JHR 49: 51–63 (2016)
doi: 10.3897/JHR.49.7929
http://jhr.pensoft.net

RESEARCH ARTICLE

JOURNAL OF Hymenoptera RESEARCH
A peer-reviewed open-access journal
The International Society of Hymenopterists

Influence of the reduction of urban lawn mowing on wild bee diversity (Hymenoptera, Apoidea)

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Academic editor: *Jack Neff* | Received 26 January 2016 | Accepted 31 March 2016 | Published 28 April 2016

http://zoobank.org/C55E0AB0-99A7-4272-B064-F8E7DA02A0D2

Citation: Wastian L, Unterweger PA, Betz O (2016) Influence of the reduction of urban lawn mowing on wild bee diversity (Hymenoptera, Apoidea). Journal of Hymenoptera Research 49: 51–63. doi: 10.3897/JHR.49.7929

Abstract

To analyse the effects of reduced green space management in urban areas on the biodiversity of insects, we compared intensely mowed lawns (mowed 12 times per year) with meadows under reduced maintenance (mowed only twice per year) in the city of Tübingen (Baden-Württemberg, Germany). Over the entire field season, 177 wild bee individuals representing 43 species were caught using sweep nets. Areas with reduced maintenance showed significantly higher total species numbers and biodiversity indices. Our research supports the initiative "Bunte Wiese (Colourful Meadow) - Species Diversity in Public Greenspaces" of the University of Tübingen, which is campaigning for the enhancement of species diversity in public urban greenland areas by reorganising intensive mowing into a "twice a year" programme.

Keywords

Colourful meadow, conservation, grassland, meadow, mowing, urban ecology, urban green space, wild bees

Introduction

Urbanisation is one of the major environmentally relevant phenomena of our time. The expansion of urban areas is rapidly increasing. In western Germany, the areas settled by humans has increased by about 140% in the past fifty years (Kompakt 2011, Russel 2005). 13.6% of the area of Germany is covered by settlements and

infrastructure (Bundesamt 2016). Fragmentation and destruction of natural areas occurs as a result of these developments (BMU 2008). Even in the countryside, intense agricultural use leads to monocultures and the loss of biological diversity (Landschaften 2006). Green spaces usually have a wide range of flowering aspects and offer a large number of niches for animals (Briemle and Fink 1993). The loss of natural grassland endangers these functions (García 1992). The intensification of grasslands (fertilization, high mowing intensity, ploughing) has a negative influence on the diversity of flowering plants and the animals depending on these resources (Haufe et al. 2015, Schuch et al. 2012).

Urban areas can offer classic nature, providing a wide range of different small habitats with positive impacts on, for instance, flower-visiting insects (Matteson et al. 2013). This explains the current focus of conservationists on these easily introduced replacement biotopes (Bischoff 1996). According to Westrich (1989), half of the German wild bee species can be found in urban areas. For example, 258 bee species have been recorded in Stuttgart (Schwenninger 1999). Although urban natural spaces cannot provide the same functions, continuity, and habitat qualities as natural areas (Müller 2005), the protection of urban nature must form an important part of all biodiversity projects (Müller 2005).

We have investigated the influence of maintenance reduction on public grasslands in the city of Tübingen (Germany, Baden-Württemberg) on the occurrence of flower-visiting wild bees. We assume that the simple reduction of the lawn mowing frequency compared with an intense monthly mowing regime in cities can make an important contribution to the international efforts to reduce the loss of biodiversity (Ade et al. 2012, Hiller and Betz 2014, Kricke et al. 2014, Unterweger et al. 2012, Unterweger and Betz 2014).

If mowing events occur too frequently and at inappropriate times, they can cause significant harm on the biodiversity of both plants and insects (Landschaften 2006). In particular wild bees (Hymenoptera, Apoidea) are highly sensitive to mowing (Buri et al. 2014, Schweitzer et al. 2012). The fast and highly engineered mowing of a flowering meadow at a warm day can kill about 50% of an entire insect population (Hemmann et al. 1987, Oppermann and Claßen 1998) and, for example, kill up to 90,000 honeybees per hectare (Fluri et al. 2000). This is possible as highly engineered mowing entails huge machines, high mowing speeds mowing and a high ground coverage per hour.so the whole foraging ground of a bee population can be cut within a few hours. Mowing affects the life on a meadow by (1) the mowing process itself, (2) the preparation for loading (swathing) and (3) the loading process (Di Giulio et al. 2001). Moreover, (4) the change of the microclimate including humidity (Albrecht et al. 2010) after mowing also contributes to the loss of faunistic biomass on meadows.

Unimproved flower-rich grassland is one of the most important habitats for bumble bees. However, in western Europe, it has been largely lost to agriculture (Goulson et al. 2008). Its restoration can boost bumble bee populations (Carvell 2002, Carvell et al. 2007). In addition, the loss of food sources leads to a decline of wild bees as they

are no longer able to feed their offspring efficiently (Buri et al. 2014). Albrecht et al. (2010) have shown the positive effect on wild bees resulting from ecological improvements in meadows (transformation into two times/year mown hay meadows) that support species richness and ecological functions. Even in private gardens, more nature and less care provide more biodiversity by offering nesting sites for bees (Lindemann-Matthies and Marty 2013).

In 2010, both students and employees of the University of Tübingen founded a pressure group to support national and international aims to protect biodiversity (Unterweger et al. 2012). This group called "Initiative Bunte Wiese" ("The colourful meadow initiative") has been instrumental in persuading decision makers to improve the maintenance of inner urban green areas with respect to conservation issues. This improvement involves (1) the reduction of mowing events towards only twice a year, (2) the use of bar mowers and (3) the removal of the mown grass from the surface (Unterweger et al. 2013, Unterweger and Braun 2015). The results of this management reduction have been evaluated in several research projects. We have investigated grasshoppers (Hiller and Betz 2014), true bugs (Unterweger 2013), beetles (Ade et al. 2012) and butterflies (Kricke et al. 2014). All these investigations have revealed a significant positive impact of reduced grassland maintenance towards species diversity and the occurrence of rare or endangered species.

In the present work, we investigate the influence of a reduced mowing regime on the diversity of flower-visiting wild bees in urban green spaces. We hypothesize that (1) endangered species are strongly linked to areas with reduced maintenance and (2) the number of both species and individuals is significantly higher in these areas.

Methods

Presentation of sampling areas

The locations of the five sampling areas in the city of Tübingen (Baden-Württemberg, Germany) are shown in Figure 1. These sampling sites were carefully selected and represent typical urban green spaces. We think that effects caused by mowing and found on these areas are representative for other areas. Each sampling site was divided into two equal study sites (200–500m^2), i.e. one was treated as a lawn (mowed 12 times per year, a common maintenance practice performed by many public garden departments), whereas the other was mowed twice a year (first cut at the end of May, second cut at the end of September).

Climate

The climatic conditions in 2010 did not significantly differ from those of the past six years. The average annual temperature was about 8.7 °C. In July, the average tempera-

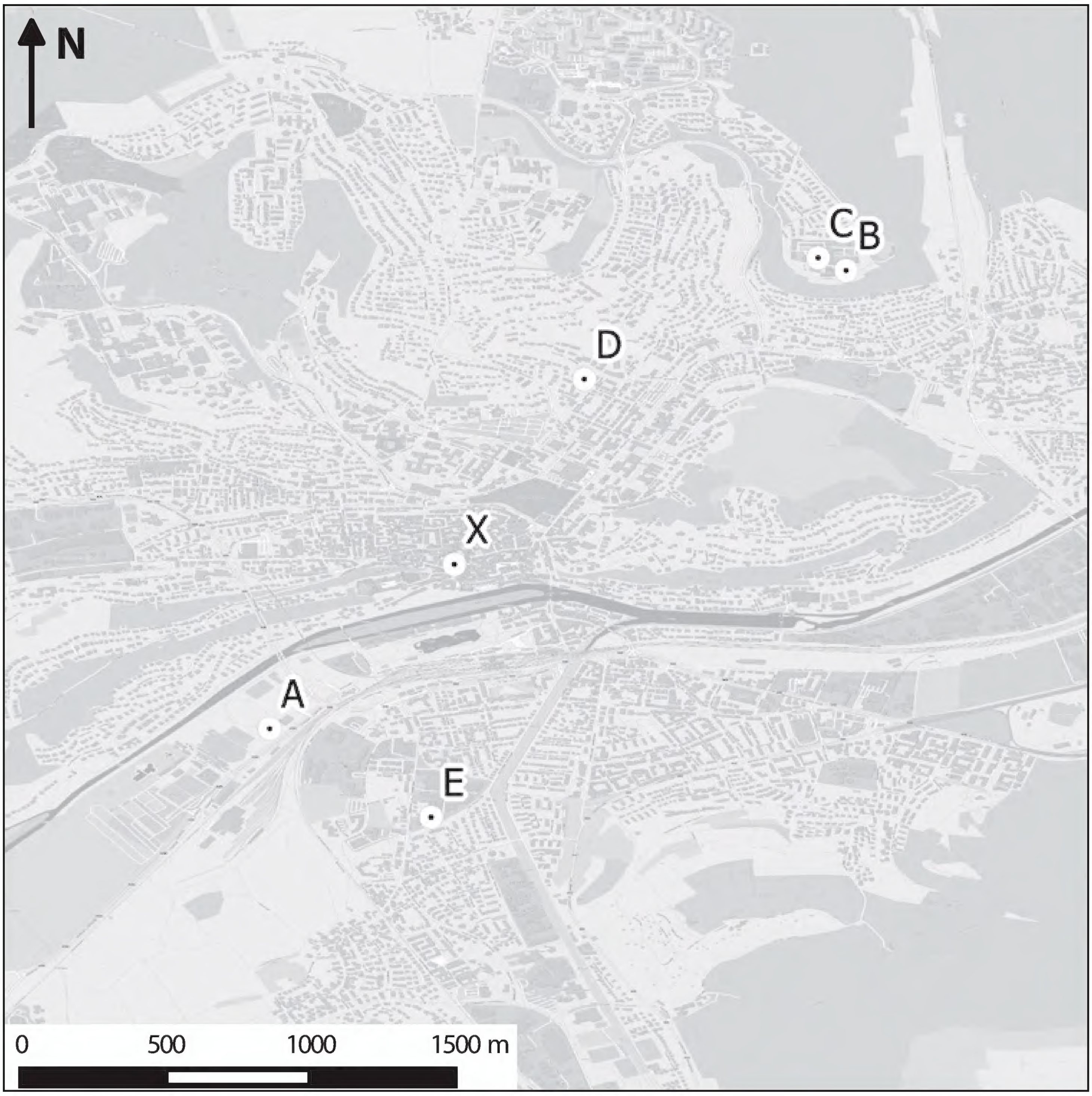

Figure 1. Map of the sampling sites in the urban area of Tübingen. A = Europastraße, B = Sand Süd, C = Sand Courtyard, D = university institute of political science, E = Julius-Wurster-Straße and X the city centre. Each area was divided into an intensely mowed lawn and an area with reduced maintenance (two cuts per year). Provided by OpenStreetMap contributors.

ture was 19.9 °C. Rainfall was rare at the beginning of the year. However, this changed in May (99 mm m^{-2}). In June and July, the weather conditions were wetter than usual but returned to normal in September.

Sampling methods

We followed the sampling methods of Schwenninger (1992). Sweep nets were used to catch the individuals from the flowering plants and the whole area. Collecting time per study site amounted to one hour per date, and management type (honeybees were

not collected as the parent species of the domesticated honeybee is extinct in Europe (Amiet and Krebs 2012).) The sampling period was between April and September 2010 with collections performed on a monthly basis. The sampling dates corresponded to warm and sunny weather.

Preparation and determination

Bees that could not be determined to species in the field were killed with ethyl acetate and carefully prepared. Genitalia were prepared if necessary. Determinations were performed according to the five volumes of Amiet (1996) and the three volumes of Scheuchl and Schmid-Egger (1997) and the aid of the Stuttgart State Museum of Natural History. The systematic classification follows Michener (2007). For species names we followed Schwarz (1996), Gusenleitner and Schwarz (2002), Westrich et al. (2008, 2012), Westrich et al. (2000).

Statistical tests

To compare the two types of maintenance, we also used the Shannon Index and Evenness to evaluate the number of species and individuals (Mühlenberg 1993).

We performed Wilcoxon-tests to check the differences between the intensely mowed lawns and the areas with reduced maintenance. All statistical analyses were performed with SPSS (SPSS 22, IBM).

Results

Species data

Over the entire sampling time, on the five pairs of sampling sites, 177 wild bee individuals representing 43 species (Table 1) were found. The sampling sites (Fig. 1) were equally distributed over the urban area of Tübingen. Threatened or declining species from both Germany (GER) and the state of Baden-Württemberg (BW) were only found on areas with reduced maintenance. In Table 1, they are shown with the IUCN (International Union for Conservation of Nature) and the BfN (German Federal Agency for Nature Conservation) standards. The number of individuals per species on the study sites varied from 1 to 21.

Plant data

The average number of dicotyledon species was to 13,6 species on the intensely mowed plots and to 15,8 species on the extensively mowed sites.

Table 1. List of bee species recorded from the five pairs of study plots. The red list categories correspond to the classifications of IUCN (3 = =vulnerable, V =near threatened). The numbers of captured individuals is also given (A = intense mowing, B = reduced management). The months of capture are marked in Roman numerals (I=January, II=February etc.). The dominance D_i and the sampling sites are presented in the last two columns. The sampling sites are named as in Figure 1. The mowing intensity is coded by numbers, i.e. 1 = intensely mowed lawn, 2 = reduced (twice a year) maintenance. Endangered species were only found on areas with reduced maintenance. The total number of caught species per month was IV = 15, V = 28, VI = 15, VII = 13, VIII = 20, IX = 11. The structure of dominance classifies species from 10–31.9% as dominant, 3.2–9.9% as subdominant, 1.0–3.1% as recendent and 0.32–0.99% as subrecendent (Igić 1999; Mühlenberg 1993).

Scientific name	Red List GER	Red List BW	No. of ind. A	No. of ind. B	month	Di	Sampling sites
Andrena cineraria (Linnaeus, 1758)			3	4	IV,V	3.95	B1,B2,D1,D2,E1
Andrena gravida (Imhoff, 1832)			5	1	IV,V	3.39	B1,E1,D1,D2
Andrena haemorrhoa (Fabricius, 1781)			0	1	IV,V	0.56	E2
Andrena labiata (Fabricius, 1781)			2	1	V	1.69	B1,C1,C2
Andrena minutula (Kirby, 1802)			0	1	V,VI	0.56	B2
Andrena minutuloides (Perkins, 1914)			0	5	VI,VII,VIII	2.82	A2,B2
Andrena nitida (Müller, 1776)			2	0	IV,V	1.13	C1,D1
Andrena ovatula (Kirby, 1802)			1	0	V	0.56	E1
Andrena strohmella (Stoeckhert, 1928)			0	1	IV	0.56	D2
Andrena subopaca (Nylander, 1848)			2	0	IV,V,VI	1.13	A1,B1
Andrena ventralis (Imhoff, 1832)			2	0	IV	1.13	A1
Anthophora plumipes (Pallas, 1772)			1	2	IV,V	1.69	A1,C2,D2
Bombus hortorum (Linnaeus, 1761)			0	1	V-IX	0.56	D2
Bombus humilis (Illiger, 1806)	vu, 3	vu, V	0	2	VI,VII,VIII	1.13	A2,B2
Bombus hypnorum (Linnaeus, 1758)			0	3	V,VIII	1.13	E2,D2
Bombus lapidarius (Linnaeus, 1758)			2	3	V-VIII	2.82	B2,C2,D1,D2
Bombus lucorum s.l. (Linnaeus 1761)			1	0	VIII	0.56	D1
Bombus pascuorum (Scopoli, 1763)			6	15	V-IX	11.86	B2,A1,A2,C2,D1,D2
Bombus pratorum (Linnaeus, 1761)			1	2	V	1.69	C1,C2,D2
Bombus sylvarum (Linnaeus, 1761)	vu, V	vu, V	0	2	VIII,IX	1.13	B2,A2
Bombus terrestris s.l. (Linnaeus, 1758)			0	5	V-VIII	2.82	B2,A2,C2
Chelostoma florisomne (Linnaeus, 1758)			6	8	V,VI	7.91	B1,B2,C1,C2,D2

Scientific name	Red List GER	Red List BW	No. of ind. A	No. of ind. B	month	Di	Sampling sites
Colletes similis (Schenck, 1853)		vu, V	0	1	V	0.56	B2
Eucera nigrescens (Pérez, 1879)			0	2	V	1.13	E1
Halictus simplex (Blüthgen, 1923)			0	2	V,VI,IX	1.13	B2,A2
Halictus tumulorum (Linnaeus, 1758)			9	6	V-IX	5.65	B1,B2,D1,D2,E1,E2
Halticus scabiosae (Rossi, 1790)		vu, V	0	3	V	0.56	B2
Heriades truncorum (Linnaeus, 1758)			0	2	VI	1.13	D2
Hoplitis leucomelana (Kirby, 1802)			0	2	VI	1.13	D2
Hylaeus communis (Nylander, 1852)			0	3	VIII	1.69	B2,A2,D2
Hylaeus gredleri (Förster, 1871)			0	1	VII-IX	1.13	A2
Hylaeus punctatus (Brullé, 1832)			0	2	VIII	1.13	A2,B2
Lasioglossum calceatum (Scopoli, 1763)			1	1	V,VIII,IX	1.13	C1,D2
Lasioglossum glabriusculum (Morawitz, 1872)		vu, V	0	2	IV, VII-IX	1.13	A2
Lasioglossum laticeps (Schenck, 1870)			2	3	IV,V,VII,VIII	2.82	B2,C1,C2
Lasioglossum leucozonium (Schrank, 1781)			2	2	V,VIII	2.26	C1,D1,D2
Lasioglossum morio (Fabricius, 1793)			4	5	IV,VII-IX	5.08	D1,D2
Lasioglossum pauxillum (Schenck, 1853)			9	14	V-IX	7.91	B2,A2,E1,C1,C2,D2,E2
Lasioglossum villosulum (Kirby, 1802)			1	0	VII-IX	1.69	B1,D1
Megachile circumcincta (Kirby, 1802)	vu, V	vu, V	0	1	V,VI	0.56	B2
Melecta albifrons (Forster, 1771)			1	1	IV,V	1.13	D1,D2
Osmia bicornis (Linnaeus, 1758)			6	8	IV,V	9.60	B1,B2,C1,C2,D1,D2
Osmia cornuta (Latreille, 1805)			0	1	IV	0.56	C2

Comparisons between intensely and extensively mowed study plots

The comparison of intensely mowed lawns with areas with reduced maintenance show significant differences, both at the species and at the individual level. Figure 2 shows that the number of species found on the intensely mowed lawns is significantly lower compared with the areas with reduced maintenance (RM) (paired t-test: $p < 0.05$, $n = 5$). The same trend (paired t-test: $p < 0.1$, $n = 5$) is visible with respect to the number of individuals (Fig. 3).

Diversity indices

The comparison of the Shannon Index revealed a significant difference between lawns and areas with reduced maintenance ($p < 0.05$). On all sampling sites, Evenness was between 0.81–0.95.

Discussion

Our results indicate that a reduction in mowing intensity has impacts on the wild bee fauna at various levels. Figure 2 shows that the reduced mowing regime results in a significant increase of wild bee species diversity. Buri et al. (2014), Goulson et al. (2008) and others have found that the abundance and richness of wild bee species significantly

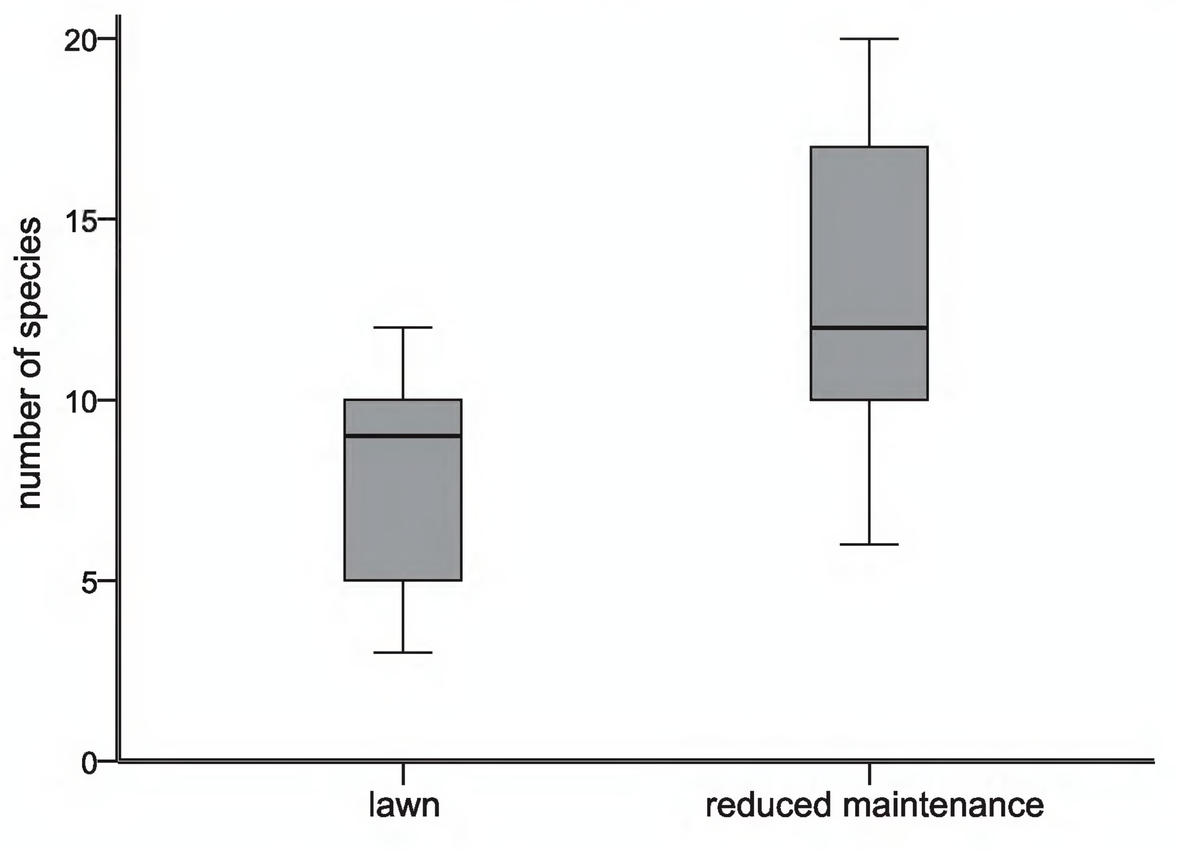

Figure 2. Boxplots showing a comparison of the number of species from intensely mowed lawns with that from areas of reduced maintenance . A Wilcoxon-test (N = 5) shows a significant difference between the numbers of species ($p = 0.042$).

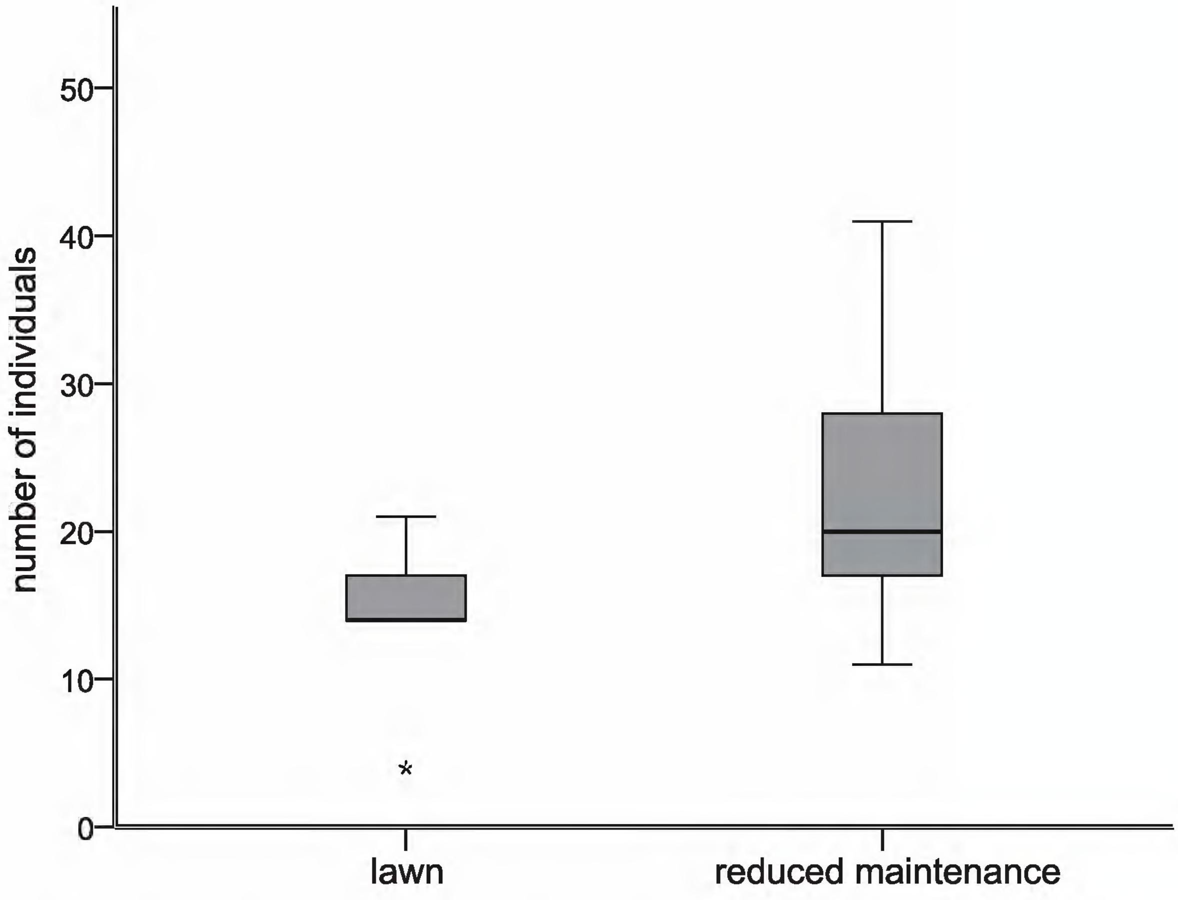

Figure 3. Boxplots showing a comparison of the number of individuals from intensely mowed lawns with that from areas with reduced maintenance. A paired t-test (N=5) shows a distinct trend toward significance (p = 0.08).

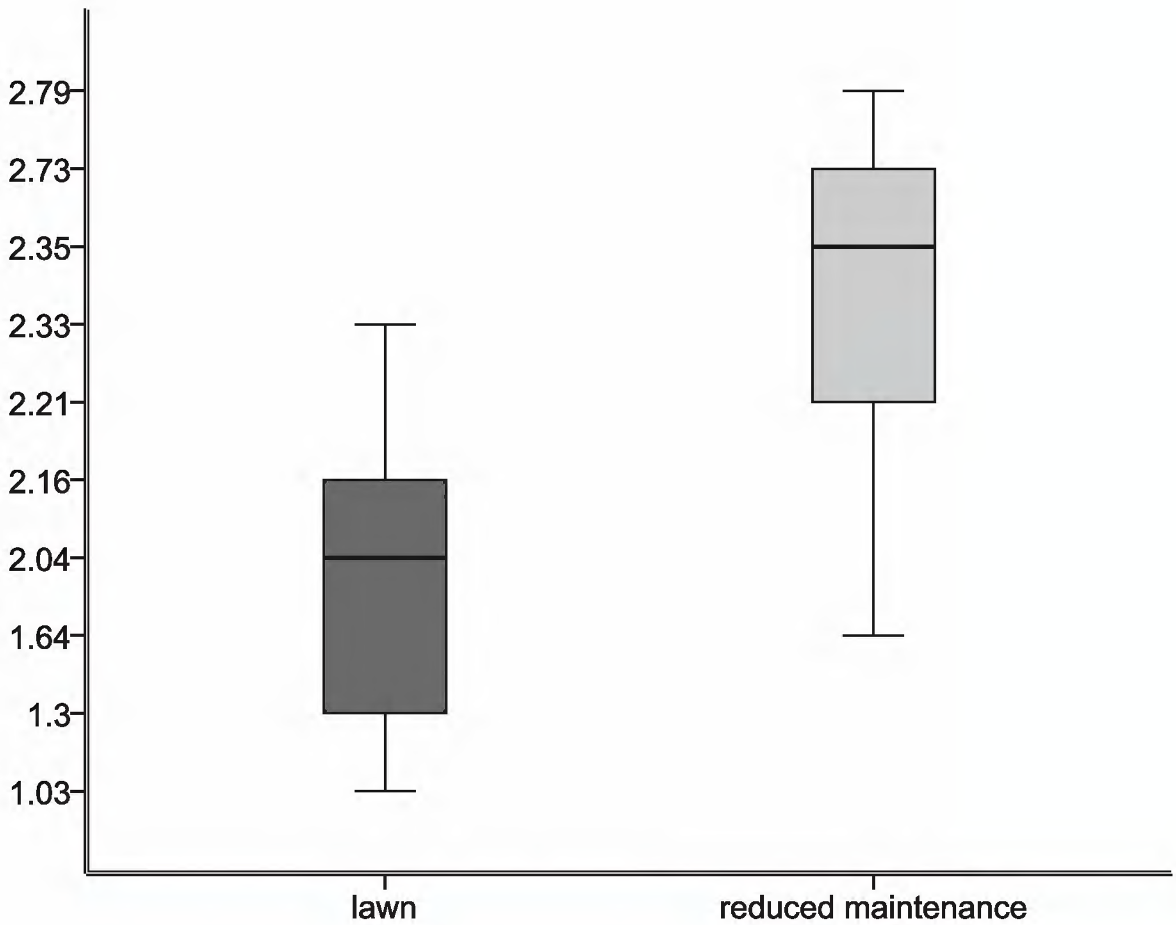

Figure 4. Boxplots showing the comparison of the Shannon Index of lawns and areas with reduced maintenance with paired t-tests shows a significant difference (p = 0.043). The Evenness values all lie between 0.81–0.95.

increases in meadows in which refuges were left uncut. The positive effects of undisturbed urban green spaces on wild bees has also been pointed out in Kutschbach-Brohl et al. (2010). This has also been confirmed for other insect orders such as beetles (Ade et al. 2012), grasshoppers (Hiller and Betz 2014), butterflies (Kricke et al. 2014) and true-bugs (Unterweger and Betz 2014). One reason for the observed differences between the intensely and extensively mowed sites can be seen in the direct effect that a single mowing event can have by reducing the number of individuals of wild bees by up to 50% (Hemmann et al. 1987, Oppermann and Claßen 1998).

Even the number of individuals of more common species can rapidly decline in areas of high mowing intensity. As seen in Table 1, single captures of species (i.e. species that could be detected only once during the investigation period) were made 12 times on areas with reduced maintenance and only four times on lawns over the whole sampling time. Six endangered species were found on the research areas and exclusively occurred on study plots with reduced maintenance. This shows the potential that a reduction of mowing intensity in public green areas can have for the conservation and maintenance of sub-populations of endangered wild bee species (Klaus 2013).

The number of sampled species had its maximum in May and August (IV = 15, V = 28, VI = 15, VII = 13, VIII = 20, IX = 11), a finding that indicates that mowing before the end of May has the greatest effect on urban wild bee populations. The importance of unmown summer meadows follows from the second peak in species richness in August. Wild bees often show a high preference for certain plant species and will benefit from the long-term reduction of maintenance (Weiner et al. 2011). It seems that cutting once per year would support wild bees the most. Nevertheless two mowing events per year has less impact than monthly mowing on the abundance and diversity of entomophilous flowering plants, which is important for nectar feeding insects.

Conclusion

Our results further support the conclusions drawn from studies of the initative "Bunte Wiese Tübingen" on other insect orders such as Orthoptera, Hemiptera, Coleoptera and Lepidoptera showing that a reduction of the maintenance of public urban green spaces supports the diversity of insects. Such actions are relatively easy to achieve in accord with local policy makers and form an effective way of meeting the demands of the global aspiration to stop the loss of biodiversity. The reduction of maintenance and the establishment of natural (infrequently, rather than intensely, mowed) green spaces and waysides can have a significant impact on mitigating the biodiversity crisis, even in our highly populated and highly degraded areas (low abundance and diversity numbers reported here indicate reduced mowing can lessen the impacts of urbanization but does not cure them) and, at the same time, increase the awareness of ecological problems occurring in urban human populations.

Acknowledgements

The English of this manuscript was corrected by Dr. Theresa Jones. Hans Schwenninger (Stuttgart) verified the species identifications. We thank the editor and our anonymous reviewers for their helpful comments.

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